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In the following step **5007**, the coupling is effected of the movements and motions of the intervention instrument with their movements simulated by three-dimensional imaging, with automatic or manual conduct of the intervention.

As noted at **5008**, the surgeon can be supplied with a permanent display of the original two-dimensional sectional images in planes specified with respect to the origin ORI and to the direction of intervention. Such a display enables the surgeon at any time to follow the progress of the intervention in real time and to be assured that the intervention is proceeding in accordance with the simulated intervention. In phase IV which is executed after the intervention, the system effects a saving of the data acquired during the intervention, this saving making it possible subsequently to effect a comparison in real time or deferred in the event of successive interventions on the same patient.

Furthermore, the saved data make it possible to effect a playback of the operations carried out with the option of detailing and supplementing the regions traversed by the active member **50**.

Thus, a particularly powerful interactive system for local intervention has been described.

Thus, the system which is the subject of the present invention makes it possible to represent a model containing only the essential structures of the nonhomogeneous structure, this facilitating the work of preparation and of monitoring of the intervention by the surgeon.

Moreover, the system, by virtue of the algorithms used and in particular by minimizing the distortion between the real base points and their images in the 2D sections or the maps, makes it possible to establish a two-way coupling between the real world and the computer world through which the transfer errors are minimized, making possible concrete exploitation of the imaging data in order to steer the intervention tool.

To summarize, the system makes possible an ineractive [sic] medical usage not only to create a three-dimensional model of the nonhomogeneous structure but also to permit a marking in real time with respect to the internal structures and to guide the surgeon in the intervention phase.

More generally, the invention makes it possible to end up with a coherent system in respect of:

the two-dimensional imaging data (scanner sections, maps, etc.)

the three-dimensional data base;

the data supplied by the marker means **3** in the reference frame R_2;

the coordinate data for the sighting systems and intervention tools;

the real world of the patient on the operating table.

Accordingly, the options offered by the system are, in a non-limiting manner, the following:

the tools and of [sic] their position can be represented on the screen;

the position of a point on the screen can be materialized on the patient for example with the aid of the laser emission device EL;

the orientation and the path of a tool such as a needle can be represented on the screen and materialized on the patient optically (laser emission) or mechanically (positioning of the guide-arm in which the tool is guided in translation):

an image of the patient, yielded for example by a system for taking pictures if appropriate in relief, can be superimposed on the three-dimensional representation modeled on the screen; thus, any change in the soft

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external parts of the patient can be visualized as compared with the capture by the scanner;

it being possible for the surgeon's field of view given by a sighting member (such as a surgical microscope) to be referenced with respect to R_2, the direction of visualization of the model on the screen can be made identical to the real sight by the sighting member;

finally, the three-dimensional images, normally displayed on the screen in the preceding description, may as a variant be introduced into the surgeon's microscope so as to obtain the superposition of the real image and the representation of the model.

We claim:

1. An interactive system for local intervention inside a region of a non-homogeneous structure to which is connected a reference structure containing a plurality of base points, the interactive system comprising:

means for dynamically displaying a three-dimensional image of a representation of the non-homogeneous structure and of the reference structure connected to the non-homogeneous structure, wherein the three-dimensional image also includes a plurality of images of the plurality of base points;

means for determining a set of coordinates of the plurality of images of the plurality of base points in a first reference frame;

means for fixing a position of the non-homogeneous structure and of the reference structure with respect to a second reference frame;

means for determining a set of coordinates of the plurality of base points in the second reference frame;

means of intervention comprising an active member whose position is determined with respect to the second reference frame;

means for generating a plurality of reference frame translation tools for translating a plurality of reference frames from the first reference frame to the second reference frame and vice versa, based on the set of coordinates of the plurality of images of the plurality of base points in the first reference frame and of the set of coordinates of the plurality of base points in the second reference frame, in such a way as to reduce to a minimum at least one of a set of deviations between the set of coordinates of the plurality of images of the plurality of base points in the first reference frame and the set of coordinates of the base points, expressed in the first reference frame using the plurality of reference frame translation tools;

means for defining, with respect to the first reference frame, a simulated origin of intervention and a simulated direction of intervention; and,

means for transferring the plurality of reference frames using the plurality of reference frame translation tools to establish a bidirectional coupling between the simulated origin of intervention and the simulated direction of intervention and the position of the active member.

2. The interactive system according to claim 1, wherein the plurality of reference frame translation tools comprise:

means for creating a matrix (M) for transferring between the first reference frame and a first intermediate reference frame based on a set of coordinates of a set of three images of a set of three base points of the reference structure;

means for creating a matrix (N) for transferring between the second reference frame and a second intermediate

reference frame based on the set of coordinates of the set of three images of the set of three base points of the reference structure; and,

means for validating matrix (M) and matrix (N) based on the set of three base points and the set of three images, such that at least one deviation between an expression for at least one additional base point in the second intermediate reference frame and an expression for at least one image point of the additional base point in the first intermediate reference frame is reduced to a minimum.

3. The interactive system according to plurality of claim 2, wherein the means for transferring the reference frames using the plurality of reference frame translation tools further comprises:

a first transfer sub-module for transferring a set of representation/non-homogeneous structure coordinates, and

a second transfer sub-module for transferring a set of non-homogeneous structure/representation coordinates.

4. The interactive system according to claim 3, wherein the first transfer sub-module comprises:

means for acquiring a set of coordinates (XM, YM, ZM), expressed in the first reference frame, of a point of the representation of the non-homogeneous structure to be transferred, by selection on the representation;

means for calculating a set of corresponding coordinates (XP, YP, ZP), expressed in the second reference frame, on the non-homogeneous structure through a transformation:

$\{YP,YP, ZP\}=M*N^{-1} *\{XM,YM,ZM\}$ where $M * N^{-1}$ represents a product of the matrix (M) and an inverse of the matrix (N), and

means for processing, with the aid of the corresponding coordinates (YP, YP, ZP), to display a corresponding point on a surface of the non-homogeneous structure and to secure the intervention.

5. The interactive system according to claim 3, wherein the second transfer sub-module comprises:

means for acquiring a set of coordinates (XP, YP, ZP), expressed in the second reference frame, of a point of the non-homogeneous structure to be transferred;

means for calculating a set of corresponding coordinates (XM YM, ZM), expressed in the first reference frame, of the representation through a transformation:

$\{YM, YM, ZM\}=N*M^{-1} *\{XP,ZP,ZP\}$ where $N*M^{-1}$ represents the product of the matrix (N) and an inverse of the matrix (M); and,

means for displaying the representation using the set of corresponding coordinates (YM, YM, ZM).

6. The interactive system according to claim 1, wherein the means for generating the plurality of reference frame translation tools also generate, in association with the reference frame translation tools, tools for taking into account a residual uncertainty which is based on the set of deviations between the set of coordinates of the plurality of images of the plurality of base points in the first reference frame and the set of coordinates of the base points, the tools for taking into account the residual uncertainty usable for displaying a set of contours in the representation whilst taking into account the residual uncertainties.

7. The interactive system according to claim 1, wherein the means of dynamic displaying the three-dimensional image comprises:

a file containing digitized data from a set of two-dimensional images constituted by successive non-invasive tomographic sections of the non-homogeneous structure;

means for calculating and reconstructing the three-dimensional image from the set of two-dimensional images; and

a high-resolution display screen.

8. The interactive system according to claim 7, wherein the means for calculating and reconstructing the three-dimensional image from the set of two-dimensional images comprises a program consisting of computer-aided design type software.

9. The interactive system according to claim 1, wherein the means for determining the set of coordinates of the plurality of base points in the second reference frame comprises a three-dimensional probe equipped with a tactile tip for delivering a set of coordinates of the tactile tip in the said second reference frame.

10. The interactive system according to claim 1, wherein the means for determining the set of coordinates of the plurality of base points is the second reference frame comprises at least one of a set of optical sensors and a set of electromagnetic sensors.

11. The interactive system according to claim 1, wherein a portion of the set of the plurality of base points of the reference structure comprises a plurality of marks positioned on a lateral surface of the non-homogeneous structure.

12. The interactive system according to claim 11, wherein the plurality of marks are four in number and are distributed over the lateral surface so as to define a substantially symmetrical tetrahedron.

13. The interactive system according to claim 1, wherein the means of intervention comprises:

a guide arm to secure intervention in the region of the non-homogeneous structure, the guide arm having a position marked with respect to the second reference frame; and,

an active intervention member whose position is marked with respect to the second reference frame.

14. The interactive system according to claim 13, wherein the active intervention member is removable and selected from the group consisting of:

tools for trephining;

needles and implants;

laser and radioisotope emission heads; and, sighting and viewing systems.

15. The interactive system according to claim 1, wherein the means for transferring the plurality of reference frames establishes a coupling between a direction of visualization of the representation of the non-homogeneous structure on the display means and a direction of observation of the non-homogeneous structure and of the reference structure by the active intervention member.

16. The interactive system according to claim 15, further comprising:

a first module for visualizing a representation in a direction given by two points;

a second module for visualizing a representation in a direction given by an angle of elevation and an angle of azimuth.

17.   An interactive system for local intervention inside a region of a non-homogeneous structure to which is connected a reference structure containing a plurality of base points, the interactive system comprising:

means for dynamically displaying a three-dimensional image of a representation of the non-homogeneous structure and of the reference structure connected to the non-homogeneous structure, wherein the three-dimensional image also includes a plurality of images of the plurality of base points;

means for determining a set of coordinates of the plurality of images of the plurality of base points in a first reference frame;

means for fixing a position of the non-homogeneous structure and of the reference structure with respect to a second reference frame;

means for determining a set of coordinates of the plurality of base points in the second reference frame; and

means for generating a plurality of reference frame translation tools for translating a plurality of reference frames from the first reference frame to the second reference frame and vice versa, based on the set of coordinates of the plurality of images of the plurality of base points in the first reference frame and of the set of coordinates of the plurality of base points in the second reference frame, in such a way as to reduce to a minimum at least one of a set of deviations between the set of coordinates of the plurality of images of the plurality of base points in the first reference frame and the set of coordinates of the base points, expressed in the first reference frame using the plurality of reference frame translation tools.

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